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Blood Oxygenation. III. The Vertical Revolving Cylinder. IV. The Vertical Revolving Cone.\*

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III. *The Vertical Revolving Cylinder.* An apparatus of design similar to the oxygenator of Gibbon<sup>1,2</sup> has been studied to determine whether its efficiency could be increased.

*Experimental.* A plastic (Plexiglass) cylinder 38 cm long and 18 cm in diameter (2200 cm<sup>2</sup> area) was mounted vertically on rollers. While the cylinder revolved, a small stream of whipped beef blood was directed onto the inner surface near the top, where it formed a film, was exposed to a 95% O<sub>2</sub> - 5% CO<sub>2</sub> mixture, and was subsequently caught in a stationary cup which fitted outside of the lower edge of the cylinder. Analyses (Van Slyke<sup>3</sup>) for oxygen were made on blood samples before and after oxygenation.

*Results.* The rate of blood flow through the oxygenator changed the volume of blood in the film. At a flow of 200 cc/min. the film content was 43 cc and at 300 cc/min. the content increased to 53 cc. Varying the rate of revolution of the cylinder (100-250 r.p.m.) did not change the volume of the film. If the blood spout was lowered half the distance to the bottom of the cylinder so that half of the cylinder area was used, the film content decreased to 25 cc at 200 cc/min. and 34 cc at 300 cc/min. Thus, the upper half of the cylinder held an average of 61% of the blood in the film when the entire drum was used. Conversely, there was an average increase of 63% in the amount of blood in the film when the area of the film was doubled, keeping the

diameter of the cylinder the same. There was no foaming in this apparatus.

An average of 11.53 cc and a maximum of 20.70 cc of oxygen was introduced into the blood per minute using the entire drum. Using half of the drum area an average of 9.32 cc and a maximum of 16.50 cc of oxygen was introduced per minute. Thus, an average of 81% of the total amount of oxygen intake occurred on half of the cylinder, which held 61% of the blood. Conversely, there was a 25% increase in oxygen uptake by increasing the film content 64% (utilizing the entire drum area). Expressed in terms of the amount of oxygen introduced into the blood per minute per unit volume of film, the entire cylinder introduced an average of 0.201 cc of O<sub>2</sub> per min. per cc of film, while the half-cylinder introduced 0.247 cc of O<sub>2</sub> per min. per cc of film. This represents an increase in efficiency of 23% by using half of the drum area with the same diameter. The maximum oxygen uptake observed was 0.470 cc per minute per cc film content using half-cylinder.

Varying the rate of revolution of the cylinder between 100 r.p.m. and 250 r.p.m. did not change the rate of oxygen uptake, though the film appeared to be less even at lower speeds.

IV. *The Vertical Revolving Cone.* Observations of the vertical revolving cylinder suggested that the greatest trauma to the blood occurs when it flies off the lower edge of the cylinder into the stationary cup. By using a funnel with a slope which will permit flow of blood downward to a small hole at the center, the trauma of transfer of the film blood to a non-rotating cup is minimized by virtual elimination of centrifugal factors.

*Experimental.* Two funnels, one 30 cm base diameter by 40 cm high, the other 20 cm base diameter by 53 cm high were re-

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<sup>1</sup> Gibbon, J. H., Jr., *J. Lab. and Clin. Med.*, 1939, 24, 1192.

<sup>2</sup> Gibbon, J. H., Jr., and Kraul, C. W., *J. Lab. and Clin. Med.*, 1941, 26, 1893.

<sup>3</sup> Van Slyke, D. D., and Neill, J. M., *J. Biol. Chem.*, 1924, 61, 523.

TABLE I.  
Comparison of Oxygenators.

	Vertical cylinder	Half vertical cylinder	30x40 funnel	20x53 funnel	Half 20x53 funnel
cc O <sub>2</sub> introduced into blood per min.					
Avg	11.5	9.3	3.3	4.6	3.8
Max.	20.7	16.5	6.4	7.3	4.9
Avg vol. content, cc	48	29	42	41	26
cc O <sub>2</sub> /min per cc blood					
Avg	.201	.247	.082	.093	.145
Max.	.390	.470	.165	.189	.195
Avg blood flow, cc/min.	250	250	200	250	250

volved in a similar manner to the cylinder, and O<sub>2</sub> analyses made on the blood before and after oxygenation.

*Results.* The efficiency of the funnel as an oxygenator was considerably less than that of the cylinder, an average of 0.10 cc and a maximum of 0.189 cc O<sub>2</sub> per minute per cc film content being introduced into the blood. The steeper funnel was the better oxygenator. Using 50% of the funnel area increased the efficiency as an oxygenator 56%. Varying the speed of rotation from 87-200 r.p.m. made no difference in the amount of oxygen introduced into the blood.

*Summary.* 1. More oxygen can be introduced into blood per unit volume of film in a vertical revolving cylinder of 18 cm diam. if segments 18 cm long are used than if the segments are 38 cm long. An increase in efficiency of 23% was obtained. 2. Speed of rotation does not, within the ranges of 100 to 250 r.p.m., affect film content or oxygenation in such a vertical revolving cylinder. 3. The vertical revolving cone does not make a good oxygenator but may conceivably be used to collect blood atraumatically from vertical cylinders.